This writeup replaces section 3 in the main writeup.

The goal of this is to explore how the lock-in amplifier can be used for experiments requiring high dynamic range and low noise. A picture of the setup is below. You will construct a box (or find a cardboard box lying around) that keeps ambient light out. Inside you will place a photodetector and two LEDs. One LED will be placed near the photodetector and be operated at a high power, such that ~ 1 mW falls on the photodetector (or as high a you can get). The other LED will have its intensity modulated sinusoidally such that the power detected by the photodetector has 1-100 nWpp amplitudes. You may choose to drive this LED with a function generator or the oscillator provided by the lock-in (with appropriate attenuation as needed).

1. Calculate the photon shot noise of the bright constant-power LED for 1 second integration time. Assuming photon shot noise is the only source of noise in the experiment, what is the smallest power modulation you should be able to detect after one second of integration?
2. Now set the lock-in time constant to a time of ~1 second. Select a modulation amplitude that you can barely see by eye when the photodetector output is plugged into an oscilloscope (probably a few hundred nanowatts). Set the modulation frequency of the LED to be equal to the demodulation frequency of the lock-in and sweep the frequency in the range 10-1000 Hz. Plot the signal strength as a function of modulation frequency and discuss.
3. Next, leave the modulation frequency of the LED fixed at a few hundred Hz and now we sweep the demodulation frequency of the lock-in amplifier from 10-1000 Hz. Record data for sufficiently long that you can calculate both the mean and standard deviation of the lock-in output for each demodulation frequency. What is the minimum power modulation you can observe above the noise floor for 1 s integration? How does this compare to the shot noise limit? What is the ideal modulation frequency of this system?